Determination of Radionuclides in Uranium Decay Chain by Gamma Spectroscopy

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Abstract

This research work is to determine the radionuclides in Uranium decay chain by gamma spectroscopy. As a reference, certified reference materials IAEA-448 and IAEA-RGU-1 were used. To calibrate the NaI (Tl) detector, standard gamma source ^{152}Eu (Spectrum Technique, USA) was utilized. Calibration ranges from 122 keV to 1408 keV. All the measurements were performed at the Experimental Nuclear Physics Lab, Department of Physics, University of Mandalay. All possible expected radionuclides from Uranium decay chain were investigated. Radionuclides from measured spectra of IAEA-448 and IAEA-RGU-1were also examined. It can be observed that ^{226}Ra (186keV), ^{214}Pb (241keV), ^{214}Pb (295keV). ^{214}Pb (351keV) and^{214}Bi (609keV) are contained in the certified reference materials.It can also be observed that net area of each Radionuclide in IAEA-448 and IAEA-RGU-1 reference samples are reliable on their present activity and gamma emission probability.

Keywords:Gamma Spectroscopy, Certified Reference Materials, Radionuclides

Introduction

Among four naturally occurring decay chains, the 4n+2 chain of ^{238}U is called the Uranium series. This series begins with naturally occurring ^{238}U and ends with ^{206}Pb. Daughter radionuclides of ^{238}U are ^{226}Ra (186keV), ^{214}Pb (241keV), ^{214}Pb (295keV), ^{214}Pb (351 keV), ^{214}Bi (609keV), ^{210}Pb (46 keV) and ^{210}Bi (226keV). This research work intends to determine the radionuclides in the Uranium decay chain by using IAEA-448 and IAEA-RGU-1 certified reference materials.

Material and Methods

In this research work, 200 g of IAEA-448 (Soil from Oil Field) and 500 g of IAEA-RGU-1 (Uranium Ore) were used. Information data on IAEA-448 and IAEA-RGU-1 are presented in Table (1). Detection system used in this research work includes Model 4002A NIM power supply, Model 296 PMT Base NaI(Tl) detector associated with amplifier 671 and multichannel analyzer. Throughout the experiment, operating voltage of negative 900 V is maintained. The multichannel analyzer sorts all incoming electrical signals according to their amplitudes. To analyze the measured spectra, Gamma Vision 32 software was used. NaI(Tl) detector is surrounded by Lead shield to reduce background radiation. The experimental arrangement forNaI(Tl) detection system is shown in Figure (1).

Detection system has to be calibrated before any measurements. To calibrate the detection system,standard gamma source ^{152}Eu (Spectrum Technique, USA) with known gamma energies was used. Information data on standard gamma source ^{152}Eu are presented in Table (2). The calibratedgamma source ^{152}Eu of known gamma energies was measured for 300 s. From the measured spectrum, calibration curve of energy versus channel number of photopeak was carried out. Measured spectrum of calibrated gamma source accumulated by NaI(Tl) detector is shown in Figure (2). Energy calibration curve for NaI(Tl) detection system

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is described in Figure (3). It shows a good linear correlation between the channel and the energy assigned to it. Energy per channel is0.86keV.

Table (1) Information Data on IAEA-448 and IAEA-RGU-1 Reference Materials

Reference Material	Radionuclide	Half-life (y)	Initial Activity (Bq/kg)	Reference Date for Decay Correction
IAEA-448	^{226}Ra	1600	19050	01 January 2009
IAEA-RGU-1			4940	01 January 1987

Table (2) Information Data on Calibrated Gamma Source

Standard Gamma Source	Gamma Energy (keV)	Half Life(y)	Initial Activity (µCi)	Present Activity (µCi)
^{152}Eu	122	13.5	1	0.9
	245			
	344			
	779			
	964			
	1112			
	1408			

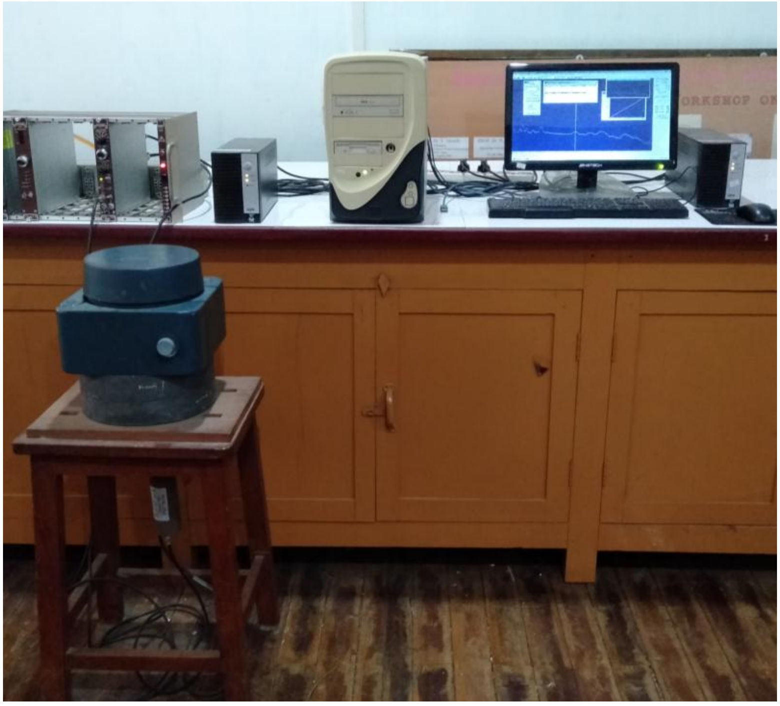

Figure (1) Experimental Arrangement forNaI(Tl) Detection System

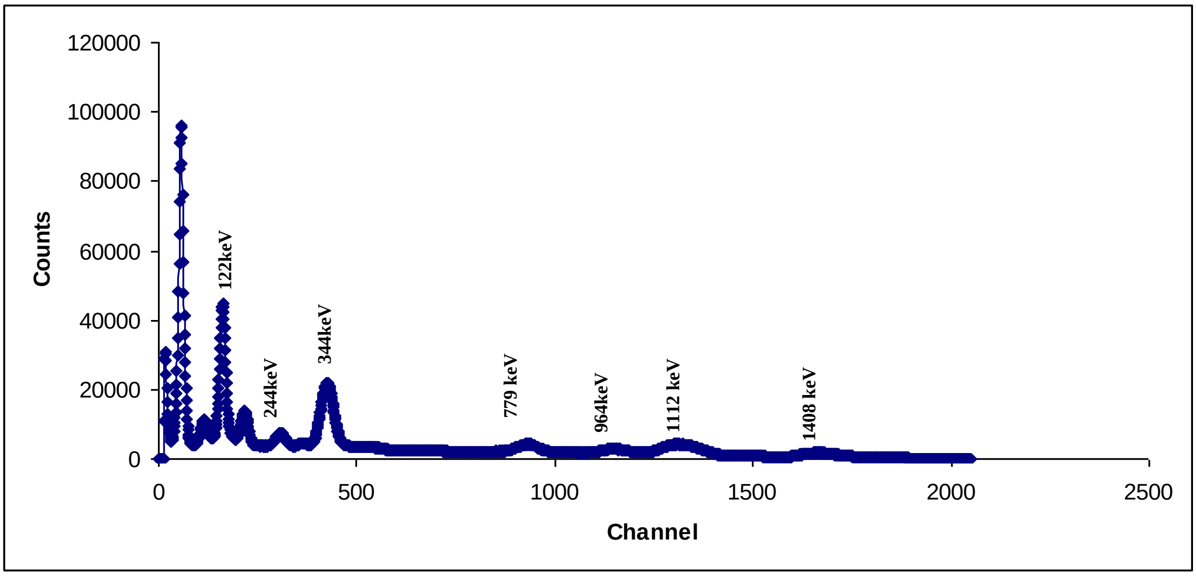

Figure (2) Measured Spectrum of Calibrated Gamma Source ^{152}Eu

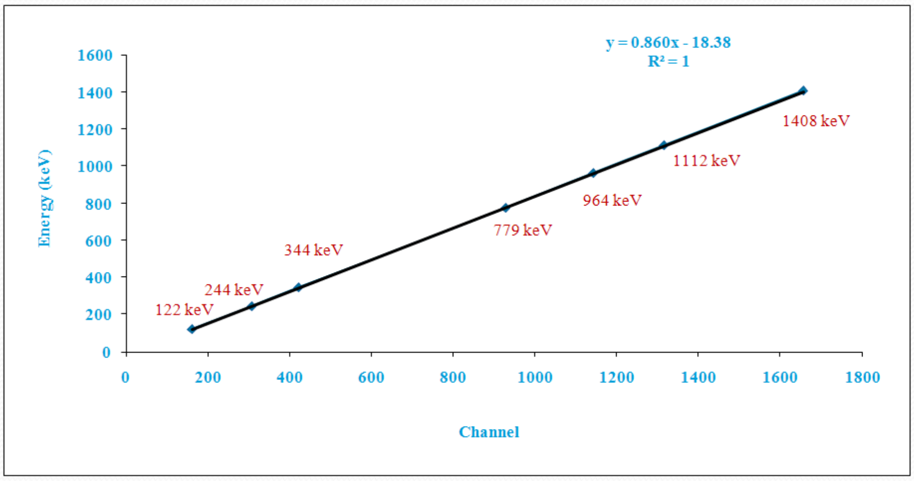

Figure (3) Energy Calibration Curve forNaI(Tl) Detection System

Result and Discussion

After calibrating the system, laboratory background spectrum was collected for 1 h. IAEA-448 and IAEA-RGU-1 reference samples, under same condition, were also measured by using NaI(Tl) detector for 1h. Sample to detector distance used in this research work is0 cm. Three – time measurements were performed on background, IAEA-448 and IAEA-RGU-1 reference samples.Measured spectra of IAEA-448 and IAEA-RGU-1 reference samples were recorded and Radionuclides contained in these measured spectra were analyzed by using Gamma Vision 32 software. Expected Radionuclides, ^{226}Ra, ^{214}Pb, ^{210}Pb, ^{214}Bi and ^{210}Bi, are described in Table (3). Comparison measured spectra of background and reference samples are illustrated in Figure (4) and Figure (5) respectively.

In determining the Radionuclides contained in the measured spectra of IAEA-448 and IAEA-RGU-1 reference samples, Parent Radionuclide ^{226}Ra and its Daughter Radionuclides, ^{214}Pb and ^{214} Bi, were observed. Daughter Radionuclides of ^{210}Pb and ^{210}Bi were not in the measured spectrum of IAEA-448 and IAEA-RGU-1 reference sample accumulated by NaI(Tl) detector. The net counts of each observed Radionuclide in the measured spectrum of IAEA-448 and IAEA-RGU-1 reference samples were obtained by marking the region of interest (ROI) for photo peak of each Radionuclide. Observed Radionuclides with their respective gamma energies are presented in Table (4). An example of analyzing the net area of an observed Radionuclide is shown in Figure (6). Net count of each observed Radionuclide for different gamma energies are mentioned in Table (5).

Table (3) Expected Radionuclides in the IAEA-448 and IAEA-RGU-l Spectra

Radionuclide	Gamma Energy (keV)
^{226}Ra	186
^{214}Pb	241
	295
	351
^{214}Bi	609
^{210}Pb	46
^{210}Bi	266

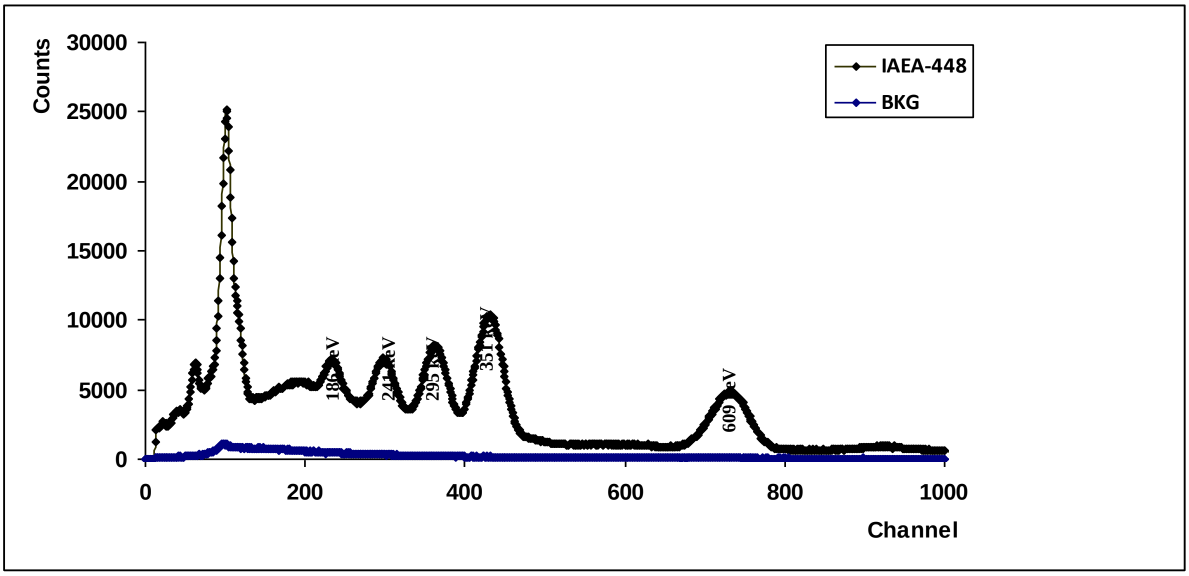

Figure (4) Comparison Measured Spectra of Background and IAEA-448 Reference Sample

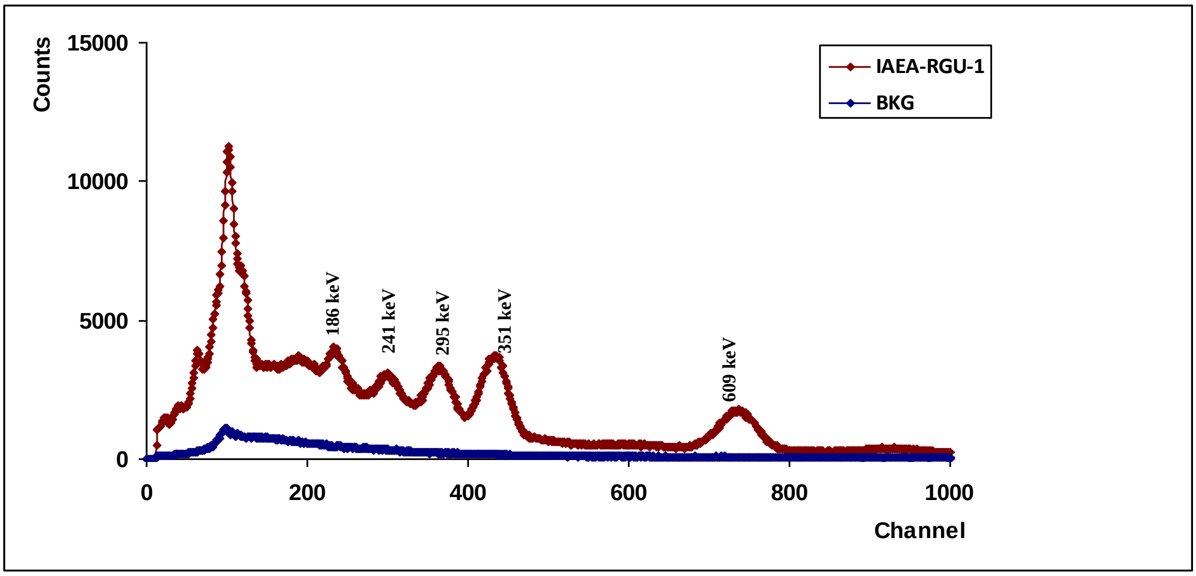

Figure (5) Comparison Measured Spectra of Background and IAEA-RGU-1 Reference Sample

Table (4) Observed Radionuclides in IAEA-448 and IAEA-RGU-l Spectra

Radionuclide	Gamma Energy (keV)
^{226}Ra	186
^{214}Pb	241
	295
	351
^{214}Bi	609

Figure (6) Analyzing the Net Area of an Observed Radionuclide (^{214}Bi at 609 keV) by using Gamma Vision 32 Software

Table (5) Net Count of Each Observed Radionuclide in IAEA-448 and IAEA-RGU-1

Radionuclide	Gamma Energy (keV)	Gamma Emission Probability (%)	Net Area (Count)	
			IAEA-448	IAEA-RGU-1
^{226}Ra	186	4	39184 ± 2388	17134 ± 8990
^{214}Pb	241	7	69645 ± 2005	17079 ± 1491
	295	19	109972 ± 3268	35456 ± 1099
	351	37	195972 ± 1792	65481 ± 5640
^{214}Bi	609	47	172509 ± 1464	58224 ± 8010

Conclusion

In determining the Radionuclides contained in the measured spectra of IAEA-448 and IAEA-RGU-1 reference samples, Parent Radionuclide ^{226}Ra and its Daughter Radionuclides, ^{214}Pb and ^{214}Bi, were observed. It can also be observed that net area of each Radionuclide in IAEA-448 and IAEA-RGU-1 reference samples are reliable on their present activity and gamma emission probability except net area for 609 keV of ^{214}Bi Radionuclide. It may be detection efficiency of NaI (Tl) detector for high gamma energy.

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